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DECONTAMINATION CONSIDERATIONS

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I. INTRODUCTION

This report is primarily for architects and engineers who are qualified **FEMA Fallout Shelter Analysts. It provides a summary of** the basic principles and procedures for radiological decontamination as well as roof washdown systems. It also provides a procedure on how to analyze the effects of radiological decontamination. Various steps can be considered by architects and engineers during the design phase of a project to improve postattack decontamination operations.

The purpose of radiological decontamination is to reduce exposure for personnel sheltered or required to work in facilities which are subjected to fallout radiation. The object is to reduce contamination to an acceptable level with the least expenditure of labor and materials, and with a minimum radiation exposure of operating personnel. The reduction of contamination is achieved by removing or covering the radioactive fallout. Generally, only a small percent of the area surrounding a facility would need priority attention for the purpose of radiation exposure control during the early postattack period. If the facility is not needed badly, removal of the fallout could be delayed until radiation levels have decreased to a tolerable level.

Decontamination should not be considered as a substitute for shelter during the early postattack period (up to 2 to 5 days). However, decontamination will allow earlier emergence from shelter in specific cases. Availability of important industries and survival resources could also require early decontamination.

This report is limited to decontamination of structures and surrounding areas and roof washdown systems. It does not include a discussion of personnel, clothing, vehicles, equipment, food, or agricultural land and water decontamination. Decontamination should be undertaken only when it is vitally needed for recovery. The problem should be evaluated for each situation, for example the location and intensity of fallout and estimated doses to operating personnel should be determined prior to any operation. Radiation instruments and visual observation would be the principal methods of identifying the extent of the problem and the effectiveness of decontamination.

II. DEFINITION OF TERMS

DECONTAMINATION.--Process of reduction or removal of radiation sources (fallout particles) from a structure, area, object, or person.

DECONTAMINATION FACTOR (DF).--The decimal fraction of the amount of fallout remaining after decontamination. If 95 percent of the fallout particle density was removed from a surface, it would result in a DF of .05.

COUNTERMEASURE FACTOR (CF).--The ratio obtained by dividing the radiation level expected or experienced at a particular point, before a countermeasure is applied, by the radiation level expected or experienced at the same point after the countermeasure is applied. For estimating the CF preattack, both measurements are assumed to be made at the same time.

SKYSHINE CORRECTION Co_a.--The radiation contribution through the roof of a structure attributed to air scattering of radiation from fallout particles on the surfaces surrounding the structure.

Co(D).--Roof contribution expected after decontamination of roof surfaces.

Cg(D).--Ground contribution expected after decontamination of ground surfaces.

Cg.--The total contribution, to the detector, of radiation originating from the contaminated ground plane and reaching the detector through the walls of the structure.

III. DECONTAMINATION PRINCIPLES

A. METHODS

Fallout will eventually settle on surfaces such as roofs, streets, tops of vehicles, and the ground. A fraction will remain in trees and shrubs depending on the amount of wind, foliage, and moisture. The main consideration of decontamination is cleaning the major horizontal surfaces. The amount of fallout expected in areas seriously contaminated by large-yield nuclear weapons may range up to an ounce of material per square foot.

Usually, decontamination methods can be classified as either wet or dry. If adequate water supply for large-scale wet decontamination is not available, dry methods can be used. Wet decontamination procedures may not be practical during very cold weather. Dry methods must be used when temperatures are so low that water will freeze before it can drain.

1. Wet Methods

Wet methods are among the most effective means for decontaminating hard surfaces such as roofs and pavements. They include firehosing, firehose lobbing, and motorized street flushing. In principle, firehosing and flushing rely on high velocity water streams to move fallout particles from high locations to drainage points at low locations.

2. Dry Methods

Paved and hard frozen surfaces may be cleaned by mechanical sweeping. Unpaved areas are decontaminated by removing the surface or covering the surface with earth. This can be done mechanically by scraper, grader, bulldozer, etc. The contribution from contaminated, unpaved surfaces surrounding the facility to be decontaminated may be reduced by plowing to bury the fallout contamination below the surface. Plowing to a depth of 8 inches is recommended. Effectiveness of decontamination is measured in terms of a decontamination factor (DF). Tables 1 through 4 in Appendix A provide Decontamination Factors for various decontamination methods, surfaces, and rates. The section on Decontamination Analysis describes methods of calculations and tables to determine quantitatively the effect of decontamination of various surfaces.

The effect of the overall decontamination of a building can be estimated by the analysis method provided in this document. This type of calculation results in a Countermeasure Factor (CF). It is somewhat analogous to PF in that it is a number greater than one and, like PF, the CF would vary from one point to another even in the same building.

B. STRUCTURES

The roof surfaces of structures are of predominant concern in the decontamination of buildings. In many cases, the roof provides a nearly horizontal surface for the collection of fallout. The roof slope, surface texture, surface features and obstructions have pronounced influence on the effectiveness and effort required for decontamination. In general, wet methods using hosing are best for roof decontamination.

The height of the roof above the ground and slope of the roof will determine the method of operation. For one-, two- and sometimes three-story buildings with very steep sloped roofs, the technique of "lobbing" the stream of water near the peak of the roof to wash off the fallout particles may be used. This technique has two

distinct advantages: first, operating from the ground, the team avoids hazards created by structurally weak, sloping, or slippery roofs; second, the set-up, moving and take-down time are greatly reduced. The "lobbing" technique is only effective on sloped roofs and its effectiveness increases as the slope becomes steeper. (It should be remembered that the steeper the roof, there is less likelihood of fallout remaining on the roof.)

To decontaminate roofs of one-to five-story buildings, standard firehosing equipment can be transported to the roof by ladder and moved about on the roof surface. This method of firehosing is particularly effective in decontaminating around obstructions. For tar and gravel roofs, the loose gravel, intermixed with fallout particles, will pile up to such an extent using firehosing or brooming methods that it will require periodic removal by hand shoveling. This type of surface is most commonly found on flat and low-pitched roofs.

For high rise buildings, the equipment will have to be transported inside the building to the roof.

In areas of high dose-rate levels, the amount of particulate matter is considerable, and the drainage system is an important consideration. Any obstruction, such as skylights, vents, or chimneys should be designed for smooth flow around them.

C. PAVED AREAS

Most buildings are surrounded by large paved areas of concrete or asphalt. Decontamination of these surfaces is best accomplished by motorized street sweepers and/or flushers. Firehosing can be used effectively for small paved surfaces and where obstructions prevent the use of motorized equipment. Storm drains or sewer systems should be of adequate size to handle all water and fallout which are washed into them.

D. NATURAL OR UNPAVED LAND AREAS

Decontamination of natural areas can be accomplished by removing the top layer of soil, covering the surface with uncontaminated soil, or by plowing under the contaminated soil. The effectiveness is dependent on the thoroughness with which the operation is conducted.

Large-scale scraping operations require heavy motorized equipment to scrape off the top several inches of contaminated soils and to carry them to suitable predesignated dumping grounds. The contaminated soil should be deposited at least 300 hundred feet beyond the facility to obtain the benefit of attenuation through

distance or be placed behind a shielding barricade. Another effective method is to scrape the top layer of soil and make earth barriers at the perimeter, creating a dike effect. This would provide a barrier shield from the direct ground contribution beyond the cleared area. The self-shielding produced by mounding would reduce the emission of radiation from the sources throughout the mound. Additional clean material could be added to the mound to reduce the radiation emission further.

Filling or covering the area with uncontaminated soil is generally not as rapid or as effective as scraping. The principal use would occur when scraping procedures could not be used, either because of rocky ground or because of permanent obstructions.

Plowing provides shielding from radiation by turning the contaminated soil under. It is a rapid means of decontamination but may not be suitable where personnel must operate or travel over the plowed surface.

E. COLD WEATHER

Cold-weather decontamination methods will depend upon the weather conditions prior to and after the arrival of fallout. The situation could vary from fallout covered with ice or snow, interspersed with a snow-fall, or fallout on the top of a snow or ice field. The presence of snow or ice would complicate the situation, since large quantities would have to be moved along with the fallout. Fallout may be clearly visible as a dark film or layer of soil or powder on or within the snow unless it falls with the snow. The normal procedures for snow removal, such as snow loading and plowing, are effective. Regular earth-moving equipment and methods can also be used in removing contaminated snow. Pavement sweepers can be used for removal of fallout from dry pavement, traffic-packed snow, or reasonable level frozen soil or ice. Firehosing is possible and can be used on paved surfaces and roofs of buildings even when ambient air temperatures are slightly below freezing.

IV. DECONTAMINATION CONSIDERATIONS

The previous Chapter on Decontamination Principles described methods and factors which influence decontamination. The significant decrease in the radiation dose rate to personnel resulting from decontamination will allow earlier emergence from shelters in specific situations and earlier occupancy and use of important facilities. Thus, certain advantages arise from designing buildings and their surrounding grounds so that decontamination can be accomplished easily, rapidly, and economically.

To optimize application of decontamination principles in designing buildings, various considerations can be given. In general, the design principles which make it easier and quicker to remove fallout particles from surfaces would be similar to those used for removal of a coarse, sand-like material from and around buildings. Thus, considerations should be given to accessibility, surface textures, water supply, and drainage.

A. ACCESSIBILITY

1. Roofs

Most radiation to occupants of one-, two-, or three-story buildings with lightweight roofs is likely to be from fallout particles on the roofs. To achieve a reasonable Countermeasure Factor with these types of buildings, the roof must be decontaminated. For flat roofs, or roofs with a moderate slope, the ease of access to the roof is very important. Access from within the buildings, such as stairways, should be provided where possible. Stair-type fire escapes as exterior accesses would be satisfactory if they extend to the roof. For large buildings with steep-sloped roofs, access to a near adjacent roof or wing would be sufficient for use of the lobbing technique.

2. Ground Areas

Large open areas surrounding buildings require motorized equipment for decontamination. Therefore, small parking lots, fences, large shrubbery and other items which might hinder the movement of equipment, becomes factors to consider in the design phase. Service lines must be placed deep enough to prevent cutting if plowing or scraping is anticipated.

B. SURFACES

Consideration should be given to the roof surface and surfaces surrounding the building which would facilitate decontamination. A smooth, hard surface is the easiest to decontaminate. For example, using a neoprene, hypolon, or similar type of coating on a concrete roof would be better than a tar-and-gravel roof. The paving of large parking surfaces near or adjacent to the facility would also facilitate decontamination.

C. WATER SUPPLIES

The location and distribution system of the water lines should be carefully considered. Normally, the amount of water required for a modern firefighting system is sufficient for decontamination operations.

During a nuclear attack, the city water supply system may be ruptured. Consideration should be given to providing a stand-by water supply sufficient for at least decontamination of the roof. Studies indicate that the amount of water required is one gallon per square foot of surface to be decontaminated. Stand-by water such as in an elevated storage tank or tanks on the roof could be useful for decontamination and also might reduce fire insurance premiums since they improve fire fighting capacity.

D. DRAINAGE

In utilizing wet methods of decontamination, the ease and effectiveness is increased if the slope of all surfaces and drainage systems is adequate to insure the movement of large quantities of material in a short time by the water. A slope greater than one to four (1:4) will not usually be a serious problem, and will provide the drainage required. Fallout carried to the ground from the roof will subsequently be removed during the ground decontamination operations.

Flat or slightly sloping roofs, which are usually used in modern, large buildings, can cause a drainage problem especially if the roofing surface is rough. The wearing surface should be smooth to achieve easy decontamination.

Drainage can be improved by paving surfaces, especially those adjacent to the building, and providing proper drainage to storm sewers or ditches. Slopes of paved surfaces should be three percent or greater to transport the fallout when using wet methods.

V. DESIGN CONSIDERATION SUMMARY

A. ROOF SURFACES

The following items should be reviewed in the design of the roof to insure better decontamination potential:

1. Composition.--The final roof surface should be as smooth and hard as possible. Newer-type surfaces such as laminated epoxy are recommended.

2. Slope.--For flushing, the slope of the roof should be sufficient to insure adequate drainage of the water. The slope of the roof will depend on the type of surface chosen. In some cases, roof slopes may be controlled by local building codes.

3. Gutters and Downspouts.--If gutters and downspouts are included in the design of the roof, they should be oversize to insure complete collection of the large amount of water and parti-

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culate matter for decontamination.

4. Obstructions.--There should be a minimum of obstructions on the roof.

5. Water Supply.--There should be access to water supply for the roof.

6. Access to Roof.--Means should be provided to allow easy access to the roof by the decontamination team.

B. GROUND AREAS

1. Terrain.--Locate building to take advantage of natural terrain features to minimize the extent of ground planes around the building. Walls or earth berms could be used for this purpose.

2. Pavements.--Asphalt or concrete pavements should be used in lieu of gravel or grassy areas.

3. Obstructions.--Minimize obstructions near the building to allow equipment to operate easily.

4. Water supply.--Some sort of water supply should be located near the building to allow flushing methods.

5. Drainage.--The ground should slope away from the building to storm sewers or ditches. A slope of three percent is recommended.

VI. ROOF WASHDOWN SYSTEMS

Although roof washdown systems are a protective measure and such systems must be installed prior to attack, calculations of its effectiveness are similar to calculations for effectiveness of decontamination. A building with a washdown system should not be considered as a shelter in the same sense as a shelter with adequate shielding. A washdown system depends on mechanical devices which have some probability of failure. However, there are situations where a roof washdown system is the only solution to improving shelter protection--for instance, where an existing building with heavily shielded walls cannot support any added roof weight for shielding.

A. BACKGROUND

The effectiveness of a roof washdown system is dependent upon the following design variables--Roofing Surface Type, Roof Slope, and Washdown Water Flow Rate. In designing a building, the architect could change all of these within certain specification limitations; however, if washdown is being considered for an existing structure the surface type and roof slope is usually fixed and the washdown water will be the only variable which can be changed to give maximum removal efficiency.

Washdown can be used to advantage on existing buildings if certain requirements are met.

1. The building must have high mass walls or be of such design that the mass thickness can be increased easily and economically, or be large enough that the occupants could be confined to a center section of the building.

2. The slope of the roof must be sufficient for each specific roof surface. (Different types of roof surfaces require different slopes). If the roof surface is tar and gravel or is similarly rough, the surface should be replaced with a suitable roof which because of its smoothness facilitates roof washdown.

3. The drain gutters on the building must be of sufficient size and slope to handle the volume of water required and the mass of fallout particles. If the drain gutters on the building cannot be increased in size, consideration should be given to elimination of the gutters and downspouts.

Numerous studies have been made on roof washdown systems. In these studies a fallout simulant with particle sizes from 44-1190 microns was used. This is a range of sizes which could be expected in areas where fallout intensity poses a significant threat. The deposition rate used in the experiments was 2 grams/ min/ft.^{2} This rate greatly exceeds the rate that would be expected in a nuclear attack. Thus, the removal efficiencies observed in the experiments should provide conservative design criteria. The washdown system operated during deposition (a 30-minute period) and for 30 minutes after. In an actual attack situation, the period of time that fallout is deposited may last for many hours. One rule of thumb is that deposition of fallout will continue for a period of time twice the amount of time it took the fallout clouds to reach the specific location from the point of detonation. For example, if the location was 60 miles downwind and the average wind velocity was 20 mph, we could expect fallout to commence 2-3 hours after detonation and continue for 4-6 hours. Thus, a washdown system should be designed to operate continuously during this fallout deposition period. To reduce the total quantity of water required, a closed system could be used. This type of system would require a shielded or buried tank with settling and filtration to remove the fallout from the supply side of the pump.

The studies used six different roofing materials: Aluminum Shingles, Composition Shingles, Roll Roofing, Tar-and-Gravel Roofing, Corrugated Galvanized Steel, and Fiberglass-Epoxy Laminate. The slopes of the roofs varied from 1:24 to 1:4. Two types of nozzles were used: Flooding type and rotary lawn sprinkler.

The results of these tests showed that the rotary lawn type

sprinklers were much more effective than the flooding nozzles on all surfaces. The largest difference in the two types of nozzles was shown at the slope at 1 to 24 (1:24) on all surfaces where the rotary nozzles were far superior. The slope became a much less important variable with the rotary nozzles. The rotary type lawn sprinklers were effective in removing 95 to 98 percent of the fallout from all five of the standard roofing surfaces tested at most slopes. The tar and gravel roof was found not suitable for a roof washdown system. The slope of the roof affected the amount of fallout remaining on the roof (residual) on all surfaces with the flooding nozzles much more than particle size did. Obstructions in the path of flow of thin water films actually causes particles to move upstream and concentrate in back of the obstruction. Large particles which failed to move had the same effect on the transport of smaller particles as a fixed obstruction.

The flow rate required using rotary nozzles was found to be 5.4 gallons per minute (gpm) at 40 pounds per square inch (psi) head with nozzles placed 10 feet on centers in rows 12 ft. on centers. Using this arrangement, the roof materials found best suited (listed from best to worst) for roof washdown were:

1. Laminated Epoxy Roof.

The fiberglass epoxy laminated roof was the easiest surface to decontaminate. At most slopes a flow from the flooding nozzles of only 0.5 gpm/ft of width was required to give better than 90% removal of the fallout. The smallest effect of fallout particles on removal rate with the flooding nozzles was shown on the fiberglass epoxy laminated roof.

2. Aluminum Shingles. The aluminum shingle surface was slightly easier to decontaminate than the roll roofing surface.

3. Roll Roofing. A roof slope of 1:24 was adequate for all the above surfaces.

4. Composition Shingle. Composition shingle was the next most difficult surface to decontaminate with the system fitted with flooding nozzles. A slope of 1:8 or higher and a water flow rate of at least 4 gpm/ft of width were required to reduce the residual mass to less than 10%. These same conditions on the aluminum shingles reduced the residual to 5% or less.

5. Corrugated Steel.

Corrugated galvanized steel showed the highest

percentage residual mass remaining of the various surfaces tested using the flooding type nozzle, particularly with the 88 to 177 μ size particles. A water flow of 7gpm/ft of width was required at all three slopes tested to reduce the residual to as low as 25%. The effect of fallout particle size on the residual retained on a roof was more pronounced on the corrugated galvanized roofing than any other surface tested. The high residual with the smaller particles is due to the fallout's sticking to the crest of the corrugations, whereas the larger particles roll down into the trough where the washdown waste is flowing. A slope of 1:8 should be used on the last two types in order to achieve efficiencies over 90 percent.

6. Tar and Gravel. As indicated previously, the tar and gravel roof was found not suitable for roof washdown systems.

B. DESIGN CRITERIA

From the various studies the following design criteria are recommended:

1. Rotary sprinklers, should be spaced 10 feet apart across the roof and in rows 12 feet apart down the roof, from crest to trough. Each nozzle should be operated at a pressure of approximately 40 psi to deliver about 5.4 gpm/nozzle. There are several possible ways for arranging the piping to achieve the desired spacing of nozzles, water pressure and flow of water. One possible arrangement is shown in Figure 1. Different piping arrangements have also been constructed and were found to be satisfactory.

2. Flooding type nozzles should be installed across the width of the roof at the crest to deliver 1 gpm/ft. of roof width. (This sheet flow produced by these nozzles will act as insurance in the event that a rotary nozzle fails to rotate.)

3. Roof Slopes

a. 1:24 Laminated Epoxy Roof
Roll Roofing
Aluminum Shingles

b. 1:8 Composition Shingles
Corrugated Steel

4. Parapet desirable to reduce wind effect on water film.

5. A recirculating water system is desirable and will make the system independent of the regular water supply, which might be interrupted by a nuclear detonation. A shielded tank must be provided

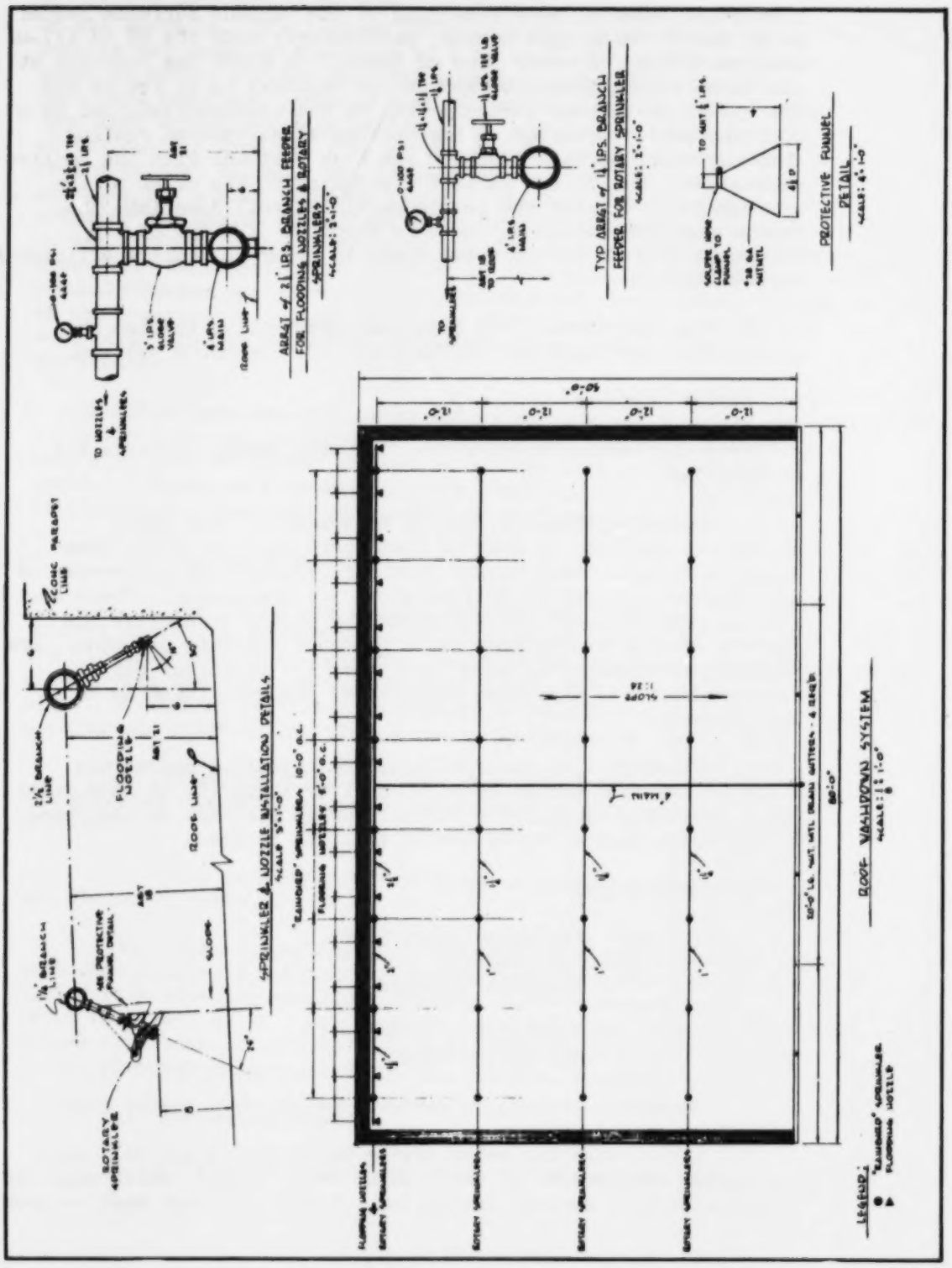
ROOF WASHDOWN SYSTEM
SPRINKLER & NOZZLE INSTALLATION DETAILS
ROOF LINE
FLOODING NOZZLES
ROTARY SPRINKLERS
PROTECTIVE FUNNEL DETAIL
TYP ARRGT OF 1½" IPS. BRANCH FEEDER FOR ROTARY SPRINKLER
ARRGT OF 2½" IPS. BRANCH FEEDER FOR FLOODING NOZZLES & ROTARY SPRINKLERS
LEGEND:
"RAINBIRD" SPRINKLER
FLOODING NOZZLE

Figure 1 Example layout for a Koot Washdown System

to contain the radioactive contamination washed from the roof.

6. Emergency power system if vital facility.

7. Adequate drainage, gutters, down spouts, etc. to handle the amount of water and fallout particles.

8. Radiation monitor to activate system or indicate when it should be turned on.

C. LIMITATIONS

The radiation contributions within a structure in considering decontamination can be broken down into the following components:

1. Transit dose--i.e., dose received from fallout particles in air. (This is approximately three percent of infinite dose.)

2. Ground Contribution

3. Roof Contribution

4. Skyshine through Roof

The roof-washdown system affects only one of these factors, i.e., roof contribution, C_o. For conservative analysis, reduction of 95 percent (DF 0.05) could be used for the epoxy and roll roofing and 90 percent (DF 0.10) for all others (assuming all other criteria are met). For a roof washdown system to be truly effective, it is particularly important that the ground component must be small. For structures with relatively thick walls or for shelter areas adequately protected by interior partitions or distance, a roof-washdown system may be considered. However, since it is an active countermeasure system, the following factors should also be considered:

1. The system must operate when needed; this means periodic testing, maintenance, and repair--a system cost.

2. The system must have reliable water supply and power.

3. The system must be hardened to the same degree as the structure itself against blast and thermal radiation.

4. Skylights, vents, or other roof obstructions must be designed to allow free flow of water.

5. The washdown system is not suitable in areas subject to freezing. The water could freeze in the pipes or nozzles causing them to burst. In addition, when temperatures are near freezing, the thin film of water on the roof could freeze creating a sheet of ice and "freezing" the fallout within the sheet of ice.

6. Wind or rain can be expected to remove some of the fallout from smooth sloped roofs. Such weather effects would probably not reduce the radiation from roof sources not removed by roof washdown but over a period of time they would decrease the radiation from shielded roofs without an operating washdown system.

D. SUMMARY

There is sufficient test information to design an adequate roof-washdown system which will remove 95 percent (DF 0.05) of the roof contamination. It should be considered only when the roof contribution is the predominant dose component since all others are unaffected by roof washdown. Since it is an active countermeasure system it must be reliable if the system must provide protection during the emergency phase. The roof washdown should only be considered as an alternate to adequate roof shielding. In general, the cost of a roof washdown system for large structures with smooth sloped roofs will be less than the cost of providing an equivalent amount of shielding. However, applied shielding provides 100 percent reliability whereas roof washdown systems may not be as reliable. (Equipment breakdown and weather conditions etc.)

VII. DECONTAMINATION ANALYSIS

This Chapter describes the shielding analysis of structures when one of the various decontamination methods previously described is to be employed. In order to fully appreciate these analyses, the reader should have a sound knowledge of the Standard Method for fallout shelter analysis as described in TR-20 (Vol. 1).

A. ROOF DECONTAMINATION

1. Discussion

Although it would be possible to analyze a building assuming decontamination of only part of a roof, it is not a practical case. Skyshine, radiation from fallout on the ground surrounding a structure, can scatter in air and enter the structure through its roof. Therefore, contribution due to radiation penetrating a roof, frequently referred to as overhead contribution, is caused by fallout on the roof and on the ground. A general expression for roof contribution then is:

$$C_o = C_{o\text{-roof source}} + C_{o\text{-ground source (Skyshine)}}$$

(The Overhead Contribution Chart 9 in TR-20 (Vol. 1) includes both components.)

Decontamination of a roof has no effect on skyshine. In fact,

decontamination of the ground nearby a structure would have little effect on skyshine, since most of the air-scattered radiation originates from distant sources. (On the average, gamma radiation must travel a relatively long distance in air before it will scatter.) Normally, the skyshine value is much smaller than the C_o-roof source value. On the other hand, when decontamination of the roof is very efficient, the skyshine can be more significant than the remaining roof contamination and may even be the predominant cause of roof contribution.

The general expression for roof contribution through a decontaminated roof, $C_o(D)$, is:

$$C_o(D) = [C_o\text{-roof source}]\,[DF] + C_{oa}\ \text{(Skyshine)}. \quad \text{VII-1}$$

where C_{oa} is the roof contribution due to ground source and the values are provided in Table 5 in Appendix A. Analysts should obtain values for DF's from Table 2 in Appendix A. Values for the C_o-roof source can be obtained from TR-20 (Vol. 1) or TR-20 (Vol. 2).

2. Example:

Given: Building Dimension 40 ft. X 100 ft.
Roof Area = 4,000 sq. ft.
Distance to Roof = 25 ft.
X_o = 60 psf
Roof is shingle type

Find: $C_o(D)$ - Roof Contribution after decontamination

Solution: From Table 2 in Appendix A, select a probable decontamination method. The method used will depend on resources available. A value is used in example problems to illustrate one analysis involved. Using firehosing at a rate of 30,000 sq. ft./hr. the expected value of DF would be .05.

Using the method in TR-20 (Vol. 1) the following is obtained:

Z/L = .25, W/L = .40 from Chart 1 we find:

$$\omega = .4$$

Therefore from Table 5 with X_o = 60 and ω = .4 the overhead contribution from skyshine is 0.00239.

Using one of the methods of fallout shelter

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analysis presented in the TR-20 series, a C_o of 0.032 is obtained.

$$C_o(D) = C_o \lceil D_F \rceil + C_{oa}$$

$$= (.032)(.05) + (.0024)$$

$$= .0016 + .0024$$

$$C_o(D) = .004$$

B. GROUND DECONTAMINATION

1. Discussion

There are four basic cases for analyzing the effects of decontamination of ground surfaces. The first one is for cases where the structure has an infinite field of view. In decontaminating a strip around such a structure, a ground contribution from the field beyond the decontaminated strip would still have to be considered. The second case is where a nearby adjacent building provides a mutual shield and decontamination of all the area between the two buildings is accomplished. The third case is where there is a mutual shield with a limited strip decontaminated. In this case, the decontaminated strip width is less than the total limited strip width. The fourth case includes multiple planes. Successive planes may be higher than or lower than the preceding plane.

A general experession for ground decontamination analysis is:

$$C_g(D) = C_{g\text{-decontaminated area}} \lceil D_F \rceil + C_{g\text{-nondecontaminated area}} \quad \text{...VII-2}$$

where $C_g(D)$ is the ground contribution expected after decontamination, $C_{g\text{-decontaminated area}}$ is the ground contribution from the area to be decontaminated and $C_{g\text{-nondecontaminated area}}$ is the radiation contribution from areas which have not been decontaminated.

The C_g value for the decontaminated area can be obtained from the various methods of shielding analysis in the TR-20 series assuming a limited field or mutual shield situation. This is multiplied by the expected value of DF obtained from the Tables in Appendix A. The C_g for the nondecontaminated areas beyond the zone of decontamination can be calculated by regular fallout shelter analysis methods.

2. Examples

a. Open Field Case

Given: Building Area = 10,000 sq. ft.

X_w = 100 psf

Width of decontaminated strip = 50 feet.

H = 3'

Find: $C_g(D)$

Solution: Assume the building is surrounded by pavement which lends itself to street sweeper decontamination. From Table 1 assume a rate of 75,000 sq. ft./hr. therefore:

DF = .09

From one of the methods of shielding analysis the C_g for the area to be decontaminated is 0.016 and the C_g for the area beyond the decontaminated areas is found to be 0.013

Therefore:

$C_g(D) = 0.016 \lceil .09 \rceil + 0.013$

$= 0.0014 + 0.013$

$C_g(D) = .0144$

---

b. Mutual Shield Case

In this problem there is no far field correction since decontamination is accomplished up to the mutual shield. Thus:

$$C_g(D) = C_g \lceil DF \rceil$$

Example:

A = 10,000 square feet

X_w = 100 psf

Width of decontaminated strip = 50 feet.

H = 3'

DF = .09

What is $C_g(D)$?

For X_w' = 100; A = 10,000, H-3', and using one of the basic methods with a mutual shield at 50 feet we find:

$$C_g = .016$$

Therefore:

$$C_g(D) = 0.016 \times .09$$
$$C_g(D) = .0014 \text{ ANS}$$

This same procedure could be used in multiple plane problems, however, when roof surfaces are below the detector level, it should be remembered that the DF's should be obtained from Table 2 in Appendix A.

Once the $C_o(D)$ and $C_g(D)$ have been determined, a reduction factor, ($R_f = C_o + C_g$) can be obtained as well as the Protection Factor ($PF = 1/R_f$). An estimated Countermeasure Factor (CF) will be the same as the calculated protection factor. A true countermeasure factor should be obtained by radiation instruments as soon as decontamination operations have been completed.

APPENDIX A

TABLE I

DECONTAMINATION OF PAVEMENTS

Method	Man-Hours per 1,000 Sq ft	Rate Sq Ft/Hr	DF	Water Gals/Sq Ft	Fuel Sq Ft/Gal
Motorized Street Sweeper	0.04	25,000	0.04		12,500
	0.02	50,000	0.06		25,000
	0.015	75,000	0.09		37,500
	0.01	100,000	0.15		50,000
Vacuumized Sweeper	0.04	25,000	0.02		15,000
	0.02	50,000	0.09		30,000
	0.01	100,000	0.25		60,000
Motorized Flusher	0.01	100,000	0.02	0.27	25,000
	0.004	250,000	0.04	0.11	70,000
Firehosing 5 men 2 nozzles	0.17	35,000	0.02	0.17	
	0.12	50,000	0.03	0.12	
	0.05	125,000	0.07	0.05	

TABLE 2

DECONTAMINATION OF ROOFS

(Firehosing - 7 men per 2 nozzles)

Roof	Man-Hours per 1,000 Sq Ft	Rate Sq Ft/Hr	DF	Water Gals/Sq Ft
Tar and Gravel	1.0	7,000	0.06	1.6
	0.5	14,000	0.12	0.8
Composition	0.6	12,000	0.03	0.8
Shingle	0.23	30,000	0.05	0.33
	0.12	60,000	0.08	0.17

TABLE 3

DECONTAMINATION OF UNPAVED LAND AREAS

Methods	Man-Hours per 1,000 Sq Ft	Rate Sq Ft/Hr	DF	Fuel Sq Ft/Gal
Scraping	0.11	9,000	0.02	1,000
Filling				
6-in Fill	0.25	4,000	0.15[a]	500
12-in Fill	0.50	2,000	0.02[a]	200
Plowing	0.04	25,000	0.20[a]	6,000
Grading	0.02	60,000	0.07[b]	15,000
Bulldozing	0.2	8,500	0.07	1,500
Grading and Scraping	0.23	9,000	0.07	1,000
Hand Shoveling	2.5	400	0.12	

[a] DF is incorrect term as fallout is shielded rather than removed.

[b] DF of surface under blade only (fallout if cast to one side only).

TABLE 4

DECONTAMINATION IN COLD-WEATHER

Method	Man-Hours per 1,000 Sq Ft	Rate Sq Ft/Hr	DF	Water Gals/Sq Ft	Fuel Sq Ft/Gal
Bare Frozen Ground					
Mechanical Sweeping	0.027	37,000	0.1		18,500
Vacuum Sweeping	0.027	37,000	0.1		22,000
Firehosing	0.27	20,000	0.5	0.6	
Bare Concrete					
Mechanical Sweeping	0.015	65,000	0.06		32,500
Firehosing, 0° F	0.27	20,000	0.04	0.6	
Packed Snow					
Mechanical Sweeping 20° F	0.017	60,000	0.07		30,000
Vacuum Sweeping 20° F	0.033	30,000	0.2		18,000
Firehosing 30° F	0.45	13,000	0.05	0.9	
15° F	0.45	13,000	0.12	0.9	
0° F	0.45	13,000	0.20	0.9	
Grading 15° F	0.055	18,000	0.03		4,500
Undisturbed Snow					
Snow Plow, Blade	0.003	330,000	0.03		125,000
Snow Plow, Rotary	0.019	53,000	0.10		18,000
Grader	0.033	30,000	0.35		7,500
Scraper	0.07	15,000	0.04		2,500

TABLE 4 (Cont.)

Method	Man-Hours per 1,000 Sq Ft	Rate Sq Ft/Hr	DF	Water Gals/Sq Ft	Fuel Sq Ft/Gal
Bare-Sloped Asphalt Shingles					
Fire Hose					
Lobbing 0° F	0.5	8,000	0.55	1.1	
Lobbing 25° F	0.5	8,000	0.33	1.1	
Hand Sweeping	1.0	1,000	0.12		

TABLE 5. OVERHEAD CONTRIBUTION FROM SKYSHINE, $C_{os}(X_o, \omega)$

X_o / ω	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
0	0.1000	0.0770	0.0570	0.0424	0.0324	0.0255	0.0190	0.0138	0.00880	0.00430
10	0.0474	0.0386	0.0306	0.0246	0.0205	0.0179	0.0150	0.0124	0.00880	0.00430
20	0.0246	0.0211	0.0177	0.0151	0.0133	0.0123	0.0109	0.00947	0.00730	0.00430
30	0.0138	0.0124	0.0108	0.00958	0.00878	0.00837	0.00761	0.00678	0.00533	0.00322
40	0.00827	0.00765	0.00686	0.00623	0.00583	0.00566	0.00521	0.00470	0.00373	0.00227
50	0.00519	0.00489	0.00446	0.00407	0.00389	0.00381	0.00354	0.00321	0.00256	0.00157
60	0.00334	0.00319	0.00294	0.00272	0.00260	0.00256	0.00239	0.00217	0.00174	0.00107
70	0.00219	0.00211	0.00195	0.00181	0.00174	0.00172	0.00161	0.00146	0.00117	0.00072
80	0.00145	0.00140	0.00130	0.00121	0.00116	0.00115	0.00108	0.000984	0.000789	0.000485
90	0.000967	0.000934	0.000869	0.000814	0.000781	0.000772	0.000723	0.000661	0.000530	0.000326
100	0.000646	0.000625	0.000582	0.000542	0.000522	0.000518	0.000485	0.000443	0.000356	0.000219
110	0.000432	0.000418	0.000389	0.000364	0.000350	0.000347	0.000325	0.000297	0.000239	0.000147
120	0.000289	0.000280	0.000261	0.000244	0.000235	0.000233	0.000218	0.000199	0.000160	0.000098
130	0.000194	0.000188	0.000175	0.000164	0.000157	0.000156	0.000146	0.000134	0.000107	
140	0.000130	0.000126	0.000117	0.000110	0.000106	0.000104	0.000098	0.000090	0.000072	
150	0.000087	0.000084	0.000079	0.000073	0.000071	0.000070				

APPENDIX B

UTILIZING COMPUTER PRINTOUTS FOR DECONTAMINATION CALCULATIONS

Introduction

The SAND (Shelter Analysis for New Designs) computer printouts can be used for decontamination calculations in the design of new buildings and for decontamination planning of existing buildings. The SAND program is a protection factor (PF) computation service offered to architects and engineers engaged in the design of new structures. Guidance to A and E's for submission through the SAND program is provided in the **FEMA publication TR-55 "Shelter** Analysis for New Designs (SAND)."

The effectiveness of decontamination for ground areas depends on several parameters; the width of the decontaminated strip; the efficiency of contamination removal, defined by a decontamination factor-DF; and the contribution remaining beyond the area of decontamination. This last factor will always be relatively important since the practical limits of decontamination operations will be within a few hundred feet of the building.

The SAND printouts do not provide information on the separate ground contributions from each sector and plane. Only the contribution from each side of the building is shown for the center detector position while total ground contribution only is given for the nine off center positions. Without knowing the contribution from the various sectors and planes, one cannot compute "exactly" the effect of decontamination. The printout aids in the identification of the source of major contributions. In the design stage provisions can be made to improve the shielding of the weak points or to include features which will improve decontamination operations. The printout information can also provide the planner with guidance for proposed decontamination operations.

Since the printout does not provide information from the various planes and sectors for ground contribution an estimate of the benefits of decontaminating can be made by the following procedure. Assume that:

1. The contribution is from an infinite field.
2. The 100 feet next to the building will be decontaminated.

The "Building Part Output Printout" is used for decontamination calculations using the center detector location. The ground contributions from the center detector are provided under columns A, B, C and D which represent the contribution from each of the building sides. The first entry under each side represents the

reduction factor contribution from aperatures on that side. The second entry represents the contribution from the solid wall on that side. The total roof contribution is provided under the "Roof" column. The printout also provides PFs as well as roof and total contribution from all sides for eight off-center detector locations. An estimate can be made of the effect of decontamination at these off-center locations by assuming an "average" decontamination factor for any or all sides of the building.

To obtain an approximate percentage of the ground contribution received from various distances surrounding a building, Figure 1 is used which shows the fraction of the total dose (contribution factor) received from within circular boundaries for different surface types. To read this chart the distance to be decontaminated out from the building should be known or estimated, as well as the type of surface outside the building. For example, if it is planned to decontaminate out to 100 feet from the building, and the surface area is paved, the contribution factor is .87. This means that 87% of the ground contribution is received from within the 100 foot radius and 13% of the ground contribution comes from beyond the 100 foot radius.

Example:

A simple example will illustrate the method. Assume the following SAND PRINTOUT information.

A	B	C	D	Roof	Total
.012	.004	.001	.014	.020	.051

In this example, sides A and D have the largest contributions. Using the assumptions noted above, we would assume that decontamination is accomplished out to 100 feet on each of these two sides of the building. The detector height is assumed to be 3 feet. The equation which applies is:

$$C_g(D) = C_{g\text{-decontaminated area}}\left[D_F\right] + C_{g\text{-non-decontaminated area}}$$

For a particular example, we would obtain the decontamination factor, DF, from the Decontamination Factor Tables. For this example, we will assume a DF value of .02. Assuming that decontamination is to be accomplished out to 100 feet and the area is paved, in referring to Figure 1 we see that the contribution factor for the decontaminated area is .87 and .13 for the non-decontaminated area.

For side A then, $C_g(D) = .012(.87)(.02) + .012(.13)$
$= .0002 + .006$ (rounded off)
$= .0018$

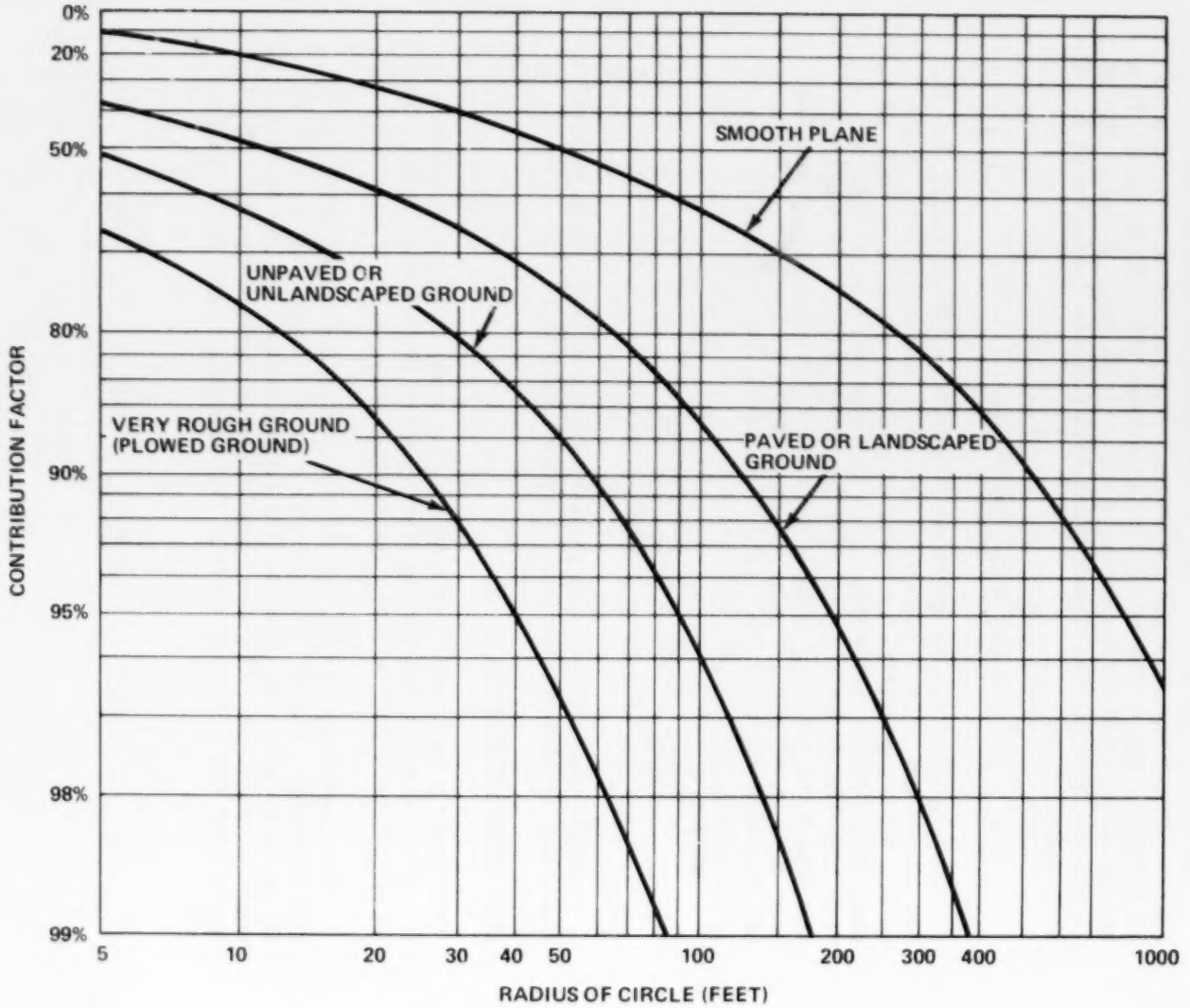

Figure 1. Contribution Factors for Circular Boundaries by Surface Types

For side D, $C_g(D) = .014(.87)(.02) + .014(.13)$
$= .0002 + .0018$
$+ .002$

In decontaminating only these two major sides, the total C_g would be reduced from .031 to less than 0.01.

For this example, the roof contribution is also a major source. Roof contribution following decontamination is estimated as follows. The value of C_o is taken from the SAND Printout from column Roof. For this example, Roof = C_o = .020. A value for DF is chosen from the Decontamination Factor Table in Appendix A. The roof equation is:

$$C_o(D) = C_o \left[\overline{D_F}\right] + C_{oa}$$

The value of C_{oa} is obtained from Table 5 in Appendix A. To use this chart, the distance to the roof, and width and length of the building must be known to obtain the ω value as well as the mass thickness of the roof. This information can be obtained from the SAND input data or from building plans. To complete the numerical example, assume that the DF chosen is .05 and the roof mass thickness if 50 psf. From Table 5, using X_o = 50, and building of 40' x 100', 25' high resulting in an ω of .4 the value of C_{oa} is .00354. Therefore:

$$C_o(D) = .020 \times 0.05 + .00354$$
$$= .001 + .00354 \text{ or } .0045$$

Under these assumed conditions, the total reduction factor would now be reduced from .051 to approximately .013.

SAND PRINTOUT EXAMPLE

Figure 2 is a SAND printout for an example building part. The first step in evaluating the benefits of decontamination is to review the contributions for each floor.

The lowest story (ST) of this building noted by "ZERO" is the basement. The PF for this story at its center is 264. This PF is well above the minimum OCD requirements. No decontamination would be required. For the first floor at ground level, (ST 1) the sum of the printout records for aperatures and solid walls are:

A	B	C	D	Roof
.02	.019	.006	.008	.007

SHELTER ANALYSIS FOR NEW DESIGNS AUGUST 26 1971
OUTPUT DISPLAY

NAME/ADDRESS/ZIP- RESEARCH BLDG 1303 MCKELDIN ST RTP NC 27709

SAND/SAF TEST _____ / 3/29/71 VERSION

SAND NUMBER- PART 1 OF 2 PARTS TOTAL NUMBER OF STORIES= 4

REVISION NO= 0 SUBMITTAL TYPE= 1 NUMBER OF SUBBASEMENTS = 0

ST	DIST TO PF=10/20 A	B	C	D	DIST TO PF=40/100 A	B	C	D	PF CENT	CENTER DETECTOR LOCATION REDUCTION FACTORS A	B	C	D	ROOF	TOTAL	PF 20 AREA	PF 40 AREA	PF 100 AREA
(0)	0	0	0	0	0	13	3	0	264	APER, 0.000	0.000	0.002	0.000			3003	2393	1669
										SOLID 0.000	0.000	0.000	0.000	0.001	0.004	(FL AB=0.000 ,FL B=0.000)		
	0	1	0	0	0	30	9	0		DET LOC	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
										ROOF RF	0.0013	0.0015	0.0291	0.0011	0.0010	0.0015	0.0156	0.0012	0.0010
										TOTAL RF	0.0038	0.0027	0.0299	0.0192	0.0019	0.0030	0.0168	0.0093	0.0023
										PF	264	369	33	52	513	336	60	108	432
										BSMT EXTN DET LOC	*A*	*B*	*C*	*D*					
										ROOF RF	******	0.0291	******	******					
										TOTAL RF	******	0.0299	******	******					
										PF	*****	33	*****	*****					
										SPECIAL DET LOC	(5, 5)								
										ROOF RF	0.0287								
										TOTAL RF	0.0293								
										PF	34								
(1)	6	16	0	0	*	*	*	*	16	APER, 0.017	0.012	0.003	0.004			0	0	0
										SOLID 0.003	0.007	0.003	0.004	0.007	0.062	(FL AB=0.001 ,FL B=0.000)		
	*	*	*	*	*	*	*	*		DET LOC	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
										ROOF RF	0.0073	0.0065	0.0064	0.0073	0.0092	0.0069	0.0068	0.0078	0.0086
										TOTAL RF	0.0624	0.0925	0.1443	0.0655	0.0800	0.0734	0.1037	0.0606	0.0736
										PF	16	11	7	15	13	14	10	16	14
(2)	0	1	0	3	*	*	*	*	28	APER, 0.001	0.002	0.001	0.001			2186	0	0
										SOLID 0.003	0.004	0.001	0.004	0.013	0.035	(FL AB=0.000 ,FL B=0.005)		
	12	18	9	13	*	*	*	*		DET LOC	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
										ROOF RF	0.0130	0.0179	0.0184	0.0217	0.0323	0.0110	0.0154	0.0114	0.0129
										TOTAL RF	0.0353	0.0504	0.0765	0.0457	0.0729	0.0368	0.0546	0.0330	0.0439
										PF	28	20	13	22	14	27	18	30	23

CONTINUED

Figure 2

ST	DIST TO PF=10/20 A	B	C	D	DIST TO PF=40/100 A	B	C	D	PF CENT
(3)	18	18	18	12	•	•	•	•	17
	•	•	•	•	•	•	•	•	
(4)	•	•	•	•	•	•	•	•	3
	•	•	•	•	•	•	•	•	

CENTER DETECTOR LOCATION REDUCTION FACTORS

	A	B	C	D	ROOF	TOTAL	PF 20 AREA	PF 40 AREA	PF 100 AREA
APER,	0.000	0.001	0.000	0.000			0	0	0
SOLID	0.001	0.001	0.000	0.001	0.052	0.061	(FL AB=0.002 , FL B=0.003)		

DET LOC	•1•	•2•	•3•	•4•	•5•	•6•	•7•	•8•	•9•
ROOF RF	0.0514	0.1233	0.1220	0.1236	0.1451	0.0421	0.0949	0.0425	0.0535
TOTAL RF	0.0604	0.1428	0.1549	0.1415	0.1680	0.0513	0.1133	0.0509	0.0631
PF	17	7	6	7	6	19	9	20	16

	A	B	C	D	ROOF	TOTAL	PF 20 AREA	PF 40 AREA	PF 100 AREA
APER,	0.009	0.027	0.009	0.040			0	0	0
SOLID	0.007	0.017	0.006	0.021	0.169	0.307	(FL AB=0.000 , FL B=0.001)		

DET LOC	•1•	•2•	•3•	•4•	•5•	•6•	•7•	•8•	•9•
ROOF RF	0.1687	0.1491	0.1357	0.1491	0.1357	0.1636	0.1570	0.1636	0.1570
TOTAL RF	0.3073	0.3135	0.3143	0.3172	0.3394	0.3069	0.3087	0.3111	0.3249
PF	3	3	3	3	3	3	3	3	3

•SUMMARY• STORY 1=FLOOR 01

STORY	PF CATEGORY 0	1	2	3	4	5	6	7	8	BASIS
0	4	61	47	26	29	22	105	10	0	FVR
1	340	0	0	0	0	0	0	0	0	A
2	345	218	0	0	0	0	0	0	0	A
3	184	0	0	0	0	0	0	0	0	A
4	0	0	0	0	0	0	0	0	0	A
TOTALS	873	979	47	26	29	22	105	10	0	

FVR - SPACES COMPUTED ON AREA BASIS
FORCED VENTILATION MAY BE REQUIRED

2-3 SPACE= 73 4-8 SPACE= 166 2-8 SPACE= 239

Figure 2 (continued)

SHELTER ANALYSIS FOR NEW DESIGNS AUGUST 26 1971
INPUT DISPLAY

NAME/ADDRESS/ZIP- RESEARCH BLDG 1303 MCKELDIN ST RTP NC 27709

SAND/SAF TEST , 3/29/71 VERSION

SAND NUMBER- PART 1 OF 2 PARTS TOTAL NUMBER OF STORIES= 4

REVISION NO= 0 SUBMITTAL TYPE= 1 NUMBER OF SUBBASEMENTS = 0

DIMENSION DATA-

TOTAL HEIGHT= 43

LENGTH OF SIDE A= 60

LENGTH OF SIDE B= 80

STORY HEIGHTS	
S BSMT	0
BSMT	10
FIRST	15
UPPER	12
UPPER CH	8 (3)

*** SIDE A ***

SECTOR	1ST	2ND	3RD
DEGREES	72	0	0
PLANE 1			
HEIGHT	0	0	0
WIDTH	999	0	0
PLANE 2			
HEIGHT	0	0	0
WIDTH	0	0	0
PLANE 3			
HEIGHT	0	0	0
WIDTH	0	0	0

*** SIDE B ***

SECTOR	1ST	2ND	3RD
DEGREES	9	32	67
PLANE 1			
HEIGHT	0	0	0
WIDTH	999	38	999
PLANE 2			
HEIGHT	0 H 25		0
WIDTH	0	30	0
PLANE 3			
HEIGHT	0	0	0
WIDTH	0	99	0

*** SIDE C ***

SECTOR	1ST	2ND	3RD
DEGREES	13	44	15
PLANE 1			
HEIGHT R	20	0	0
WIDTH	20	20	999
PLANE 2			
HEIGHT	0	20	0
WIDTH	99	15	0
PLANE 3			
HEIGHT	0	0	0
WIDTH	0	999	0

*** SIDE D ***

SECTOR	1ST	2ND	3RD
DEGREES	69	39	0
PLANE 1			
HEIGHT P	35 H	10	0
WIDTH	43	20	0
PLANE 2			
HEIGHT	0	0	0
WIDTH	999	80	0
PLANE 3			
HEIGHT	0	0	0
WIDTH	0	0	0

APERTURE DATA

	A WD	A L	A H	B WD	B L	B H	C WD	C L	C H	D WD	D L	D H
AREAWAY	0	0	0	0	0	0	3	0	7	0	0	0
BASEMENT	0	0	0	0	0	0	0	0	0	0	0	0
FIRST	30	0	8	32	210		20	210		16	210	
UPPER STORY	20	2	8	36	2	8	20	2	8	20	2	8
UPPER STY CH	12	0	5	24	0	5	12	0	5	24	0	5
STORY CHANGE		(4)			(4)			(4)			(4)	

BASEMENT EXTENSION

	A	B	C	D
LENGTH	0	20	0	0
PSF	0	75	0	0

PARTIAL BASEMENT LOC

A1= 42,B1= 0 A1= 0,B1= 0

A2= 80,B2= 60 A2= 0,B2= 0

SPECIAL DETECTOR

STORY	LOCATION
B	5, 5
F	0, 0
UP	0, 0
(0)	0, 0
(0)	0, 0
(0)	0, 0

INTERIOR PARTITIONS

STORY	D 1	P	D 2	P	D 3	P	D 4	P
BSMT-A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
FIRST-A	0	0	0	0	0	0	0	0
B	25	28	35	28	0	0	0	0
UP-A	0	0	0	0	0	0	0	0
B	25	28	35	28	0	0	0	0
(3)-A	20	52	80	52	0	0	0	0
B	15	52	45	52	0	0	0	0
(4)-A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
(0)-A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0

EXTERIOR WALL PSF

STORY	SIDE A	B	C	D
AREAWAY	0	0	100	0
BASEMENT	100	100	100	100
FIRST	87	87	87	87
UPPER	87	87	87	87
UPPER CH	52	52	52	52
STORY CH	(4)	(4)	(4)	(4)

SETBACKS AND/OR OVERHANGS(-)

	STY	A	B	C	D
SB1	2	-20	0	0	0
SB2	4	20	15	20	15
SB3	0	0	0	0	0

ROOF PSF AND FLOOR PSF

BSMT FL=	0
FIRST FL=	80
UP FL=	40
UP CH FL=	30
STORY CH=	4
OFFSET 1=	40
OFFSET 2=	25
OFFSET 3=	0
ROOF=	17

AREAWAY DATA

AREAWAY	1ST	2ND	3RD	4TH
SIDE	C			
STORY	0	0	0	0
HEIGHT	0	0	0	0
WIDTH	4	0	0	0
LENGTH	8	0	0	0
DIST,	36	0	0	0

POSSIBLE ERRORS-
3322 SIDE B ALL PLANES OF SECOND SECTOR DO NOT ADD UP TO 200 FEET.
3313 SIDE C ALL PLANES OF FIRST SECTOR DO NOT ADD UP TO 200 FEET.
3324 SIDE D ALL PLANES OF SECOND SECTOR DO NOT ADD UP TO 200 FEET.

Figure 2 (continued)

The PF for this center detector point is 16. If decontamination were considered for this floor, sides A and possibly B are the prime candidates for investigating the value of decontamination.

For the second floor (ST 2), the center detector contributions are:

A	B	C	D	Roof
.004	.006	.002	.005	.013

The roof contribution is now the major factor. If the roof contribution could be eliminated, the center PF of this story would be approximately 59, thereby making it suitable for shelter.

The third floor contributions are:

A	B	C	D	Roof
.001	.002	.000	.001	.052

The ground contribution for this floor is negligible. If the roof contribution could be reduced, the PF of this floor could be greatly improved.

The SAND printout indicates ground contribution values for a "fourth" floor. Figure 3, however, indicates that the fourth floor is really a high bay continuation of the third floor. The readings then for this floor are primarily the contribution from the third floor roof. This example points out the need for adequate information and sketches. The Input and Output data can often be misinterpreted. This example also points out a situation which could be important, i.e. the presence of roof ground planes for the upper stories of stepped type buildings. Normally ground contribution decreases as a function of height above the primary ground plane. For the "fourth" floor of this example, one can observe that the most important planes are now the limited planes of the building roof. If this was a real floor, the ground contribution would be reduced by decontaminating these roof areas. In this situation, there would not be a farfield contribution. A similar situation can arise from the lower adjacent buildings.

NUMERICAL SOLUTION

After surveying the printout data, a numerical estimate can be made for those floors where decontamination can significantly reduce radiation exposure rates. In addition to the printout, certain basic data about the building must be known. This may be obtained from the input data or directly from the plans and specifications. For this example, assume the roof is composition. From Table 2, in Appendix A the expected value of DF is .03. From the input data and the building sketch, the area of the second and third

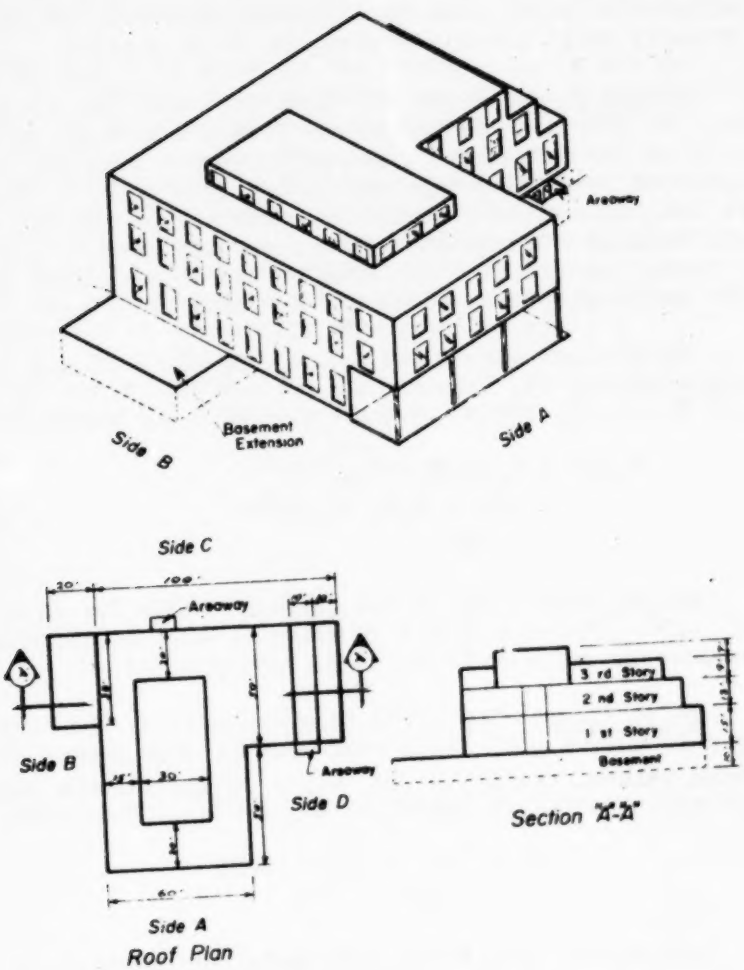

Figure 3. Hypothetical Building Used in SAF Example.

floors is 6000 square feet. The second floor is 12 feet high. The third floor including the loft area is 16 feet high. The mass thickness of the upper floors is 40 psf and the roof is 17 psf.

First Floor: For this floor the ground contribution is the major source. C_g for this floor is 0.053. Assume decontaminating out to 100 feet and an infinite field, the reduction of ground contribution would be, at most, a factor of two. The previous example indicates this potential reduction. At best, then, we could reduce C_g to about .027. This is still too high for good shelter. Unless some modification was made to the structure the first floor would not provide PF 40 shelter with decontamination out to only 100 feet. Decontaminating out to 150 feet probably would provide equivalent PF 40 shelter.

Second Floor: From the input data and the printout, the roof is the major contributor. From the sketch, we see that the roof of the loft area is the major source area for the center detector. Assuming that the entire area would be decontaminated, we can neglect the contribution from the peripheral roof since any residual contamination sources would have to penetrate the interior partitions. The area of the loft is 1800 square feet; The z-distance is 25 feet; the X_o value is 57 psf.

Using these values the Z/L = .42, W/L = .6 and the ω = approximately .3, then the C_{oa} is .00248. Since C_o is .013 and DF is .03, the estimated value of $C_o(D)$ would be:

$$\begin{aligned} C_o(D) &= C_o \times DF + C_{oa} \\ &= .013 \times 0.03 + .00248 \\ &= .00287 \end{aligned}$$

Adding this value to the printout value for C_g we get a total of .0198. This is over a PF value of 40. Decontamination could reduce the radiation dose rates satisfactorily.

Third Floor: The third floor values for the loft area are: X_o = 17 psf; Z = 13 feet; roof area is 1800 square feet. Using these values, the Z/L = .22, W/L = .6 and the ω = approximately .07 then the C_{oa} is approximately 0.0011. Therefore:

$$\begin{aligned} C_o(D) &= .052 \times .03 + .0011 \\ &= .0026 \end{aligned}$$

Adding this estimated roof contribution value to C_g, the total estimated contribution after roof decontamination would be .0066, which provides a greater PF than 40.

SUMMARY

For many structures, the roof contribution can be the most important source. Roof decontamination, then, should provide a significant reduction of radiation dose rates. The estimated roof contribution after decontamination can easily be computed by the method shown above. The ground contribution problem is more complex. Decontamination is practical for only a few hundred feet from a building. For this reason, there will usually be a significant farfield contribution. The data from the printouts is also not detailed enough for completely meaningful computations. As a rough rule of thumb, then, for cases where the farfield contribution is significant, the analyst can assume that ground contribution will be reduced by a factor of two by decontamination.

Consideration should be given by the designer to "slanting" features which will improve decontamination operations. In some situations, roof washdown systems could be considered. With a decontamination option available, shelterees who were heavily crowded during the early period of fallout, could be moved earlier than otherwise into the upper spaces after decontamination. If this was a vital facility, such as a communication center, public utility, medical facility, food distribution center, etc., proper consideration of the roof design would allow the facility to be put back into operation at an earlier time post attack.

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